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DRIVERS OF PRODUCTION AND EFFICIENCY OF ONION CULTIVATION IN BANGLADESH

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Abstract

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The study identifies the drivers of production and technical efficiency in onion cultivation based on a survey of 300 farmers from three different major onion growing districts in Bangladesh by applying a stochastic production frontier approach. Results reveal that land is the most important driver of production (elasticity value 0.33) followed by labour (0.24) and seed (0.18). Use of modern seed significantly improves production. A constant returns to scale exists in onion production. The mean technical efficiency is estimated at 67% implying that output can be increased substantially by 49% by eliminating inefficiencies in production. Extension contact, use of recommended dose of fertilizers and non-agricultural income significantly improve technical efficiency. Efficiency is significantly higher for owner operators and diversified farms. Policy implications include investments in extension services and land reform measures to improve land ownership in order to boost onion production in Bangladesh.

Key words: onion cultivation; stochastic production frontier approach; technical efficiency; Bangladesh

Introduction

Spice production, in general, is a lucrative option as it has the potential to provide higher returns to farmers as compared to conventional crops, e.g., paddy or wheat. Among the world's largest ten onion producing countries, five are from Asia, namely, China, India, Iran, Pakistan and Republic of Korea. China and India rank top in the list of producers and exporters, with China being the top producer and India as the lead trader. Taken together these two countries in 2012 produced nearly half of the world's total onion production estimated at 39 013 mt and supplied nearly one-fourth of the total international trade estimated as 2148 mt valued at USD 588 million (FAOSTAT, 2015).

Onion is the most common spice in Bangladeshi cuisines and ranked first among all spices in terms of production and area, occupying 42% of the total spice area in 2011/12 (BBS, 2013). The total area and production of onion was 135 570 ha and 1.16 million t in 2011/12 which was 11.1% and 18.8% higher than 1997/98, respectively (BBS, 2013). But the trend in annual growth rates for area and production of onion was uneven with major upward shift observed during 2003–2006 period, then declined during the 2006–2009 and later increased slightly during 2009–2012 period (BBS, 2013).Meanwhile, compared to 1999/2000, the per capita availability of onion has increased by seven folds to 7.7 kg in 2011/12 (BBS, 2013). Nevertheless, Bangladesh has imported 374 213 t of onion valued at US$ 66.8 million in 2012 (FAOSTAT, 2015).

Inadequacy and instability in domestic production made price volatility a common feature in the onion market. For instance, onion price almost tripled in the month of October 2013 in one year (DAM, 2013). Therefore, ample scope remains to encourage domestic production. Diversification

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to cash crops like onion from rice based monoculture has several benefits. Diversification promotes sustainable rural growth and improves resource utilization in the process (Barghouti et al., 2004). Diversification can also tackle technical and economic risks associated with monoculture. Diversification from rice monoculture ensured attractive financial return, particularly to the small farmers, in Thailand (Kasem and Thapa, 2011).

Bangladesh faces a closing land frontier and the prospect of increasing production by increasing land area has been exhausted since the 1980s (Husain et al., 2001). Furthermore, it is estimated that annually 1% of the country's agricultural land is diverted to non-agricultural purposes (Planning Commission, 2009). Therefore, most viable option to increase production lies in increasing productivity through eliminating inefficiency in the production process. This is particularly important for Bangladesh because existing mean yield of onion is very low estimated at 8.69 t/ha as compared to the world average of 18.33 t/h (FAOSTAT, 2015). Onion production is profitable in terms of gross returns in Bangladesh when compared to its competitive crops like mustard, groundnut, and cabbage (Haque et al., 2011), even though onion growers are not fully efficient in their resource allocation decisions (Awal et al., 2004). The volume of literature about technical efficiency in Bangladesh agriculture is quite healthy though most focused on rice farming (Wadud and White, 2000; Rahman, 2003; Rahman and Rahman, 2008; Asadullah and Rahman, 2009; Anik and Bauer, 2015). This may not be surprising as rice is the major crop in the country. Only Baree et al. (2011) analysed technical efficiency of the onion growers using a restricted Cobb-Douglas stochastic frontier production function. However, the study offers limited policy interventions as it did not include several important production (e.g. irrigation, pesticides, improved variety, etc.) and inefficiency factors (e.g. resource ownership, access to credit, crop diversification and off-farm income, etc.) highlighted in the literature. Furthermore, use of Cobb-Douglas model has severe theoretical limitations as it impose prior restrictions on the farm technology by restricting the production elasticities to be constant and the elasticities of input substitution to unity (Wilson et al., 1998).

Given this backdrop, the specific objectives of the present study are: (a) to identify key drivers of onion production; and (b) to measure the level of technical efficiency and identify their determinants. The contribution of our study to the existing literature are that we have: (a) used a wider range of production inputs and socio-economic factors to explain observed inefficiency in production; (b) used the flexible translog functional form following appropriate test of model selection; (c) tested validity of the theoretical assumptions of the model; and (d) estimated elasticities of the factors influencing technical efficiency including 95% confidence intervals of the point estimates of individual farmers.

Methodology

Data and survey

The study is based on a cross-sectional data collected from 300 onion growers belonging to six villages in the three major onion growing districts of Bangladesh. Multi-stage sampling technique was employed to locate the districts, then the upazila (sub-districts), the villages in each sub-district, and finally the sample households. The purposively selected three districts for the study were Pabna, Faridpur and Rajshahi. From each district, highest onion producing sub-district, and from each sub-district, top two onion producing villages were purposively selected. Finally, from each village, 50 onion growers were randomly selected by utilizing the list of onion growers available with the local agricultural extension offices as the sampling frame.

The econometric model

To analyse the drivers of production and inefficiency in onion cultivation, we utilize the stochastic production frontier approach which allows joint estimation of the production technology and associated level of technical inefficiency of the producers. The specific form of the translog stochastic production frontier for the i^{th} farm is defined as:

$$\ln y_i = \alpha_0 + \sum_{j=1}^{6}\alpha_j \ln x_y + \frac{1}{2}\sum_{j=1}\alpha_{jj}(\ln x_{ji})^2 + \sum_{j=1}^{6}\sum_{k=1}^{6}\beta_{jk}\ln x_{ijk}\ln x_{ijk} + $$
$$+ \tau_{OM}OM + \tau_{MV}MV + \nu_i - u_i \quad (1)$$

and,

$$u_i = \delta_0 + \sum_{d=1}^{8} z_y + \omega_i \quad (2)$$

where the dependent variable y_i is the quantity of onion produced by the i^{th} farm (kg per farm); x_is are the different production inputs; OM and MV are the dummy variables accounting for the use of organic manure and modern varieties, respectively; ν_i is the two sided symmetric, normally distributed error term; u_i is a non-negative random variable, associated with the technical inefficiency in onion production presented by z_i; and the unobservable random error ω_i is assumed to be independently distributed with a positive half normal distribution. All the variables used in the translog production function were measured at the farm level. The input variables used to explain production are: quantity of labour (man-days), quantity of seed (kg), quantity of chemical fertilizers (kg.), cost of pesticides (BDT), cost of irrigation (BDT), and quantity of land under onion production (hectare). All the input variables were mean corrected ($x_{ik} - \overline{x_k}$) prior to estimation. This is because the coefficients of the interaction variables multiplied by the same variable evaluated at the sample mean will be zero and, therefore, the coefficients on the first order term can be read directly as elasticities.

The inefficiency variables included in the model are: a satisfaction index for extension service, where a higher value indicates higher level of satisfaction; dummy variable representing access to formal agricultural credit facilities (1 for farmers with access to credit, 0 otherwise); annual off-farm income of the household (BDT); Herfindahl index of crop diversification, the value of the index is from 0 to 1 and higher value represents specialization; dummy variable for farmers using recommended fertilizer dose (1 for farmers using recommended dose, 0 otherwise); dummy for Pabna district (1 for farmers in Pabna district, 0 otherwise); and dummy variable for Rajshahi district (1 for farmers in Rajshahi district, 0 otherwise).

The maximum likelihood estimates for all parameters of the stochastic frontier and inefficiency model are simultaneously obtained by using the software program STATA 11, which estimates variance parameters that are expressed in terms of: $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $\gamma = \sigma_u^2 + \sigma$ (Battese and Coelli, 1995).

Technical efficiency of a farm lies between zero and one and is the ratio of the observed output for the farm, relative to the potential output defined by the frontier function. Given the specifications of the stochastic frontier models, the technical efficiency of the i^{th} farm, is equal to:

$$TE_i = \frac{y_i}{\exp(x_i\beta)} = \frac{\exp(x_i\beta - u_i)}{\exp(x_i\beta)} = \exp(-u_i) \tag{3}$$

Results

Summary statistics of the variables used in econometric analysis

The summary statistics of the variables used in the translog production frontier function are presented in Table 1. On average, a farm cultivated onion in 0.27 hectare of land and produced 4406 kg of onion using 7.14 kg of seed and 189.52 kg of fertilizers. The average cost for pesticides and irrigation were 2005.67 BDT and 1727.41 BDT respectively. The whole production process required 50.04 man-days of labour. More than 80% of onion growers applied organic manure. Only 13% of the farmers cultivated modern varieties. Own land constituted 83% of the total land area under onion production. The value of the Herfindahl crop diversification index was computed at 0.34 implying that the sample farmers practice a diversified cropping system, which was also observed by Rahman (2008). The value of 0.38 for the index constructed to measure farmers' satisfaction about extension service means that farmers were not satisfied with extension services. Agricultural credit from the formal sources was taken by 27.4% of the onion growers. Annually a farm household earned 23,034 BDT from non-farm activities. Nearly one out of every three farmers used recommended fertilizer dose (Table 1).

Table 1
Summary statistics of the variables used in the production function (per farm basis)

Variables	Mean
Variables used in production function	
Quantity of onion produced (kg)	4405.01
Labour (man-days)	50.04
Seed (kg)	7.14
Fertilizer (kg)	189.52
Pesticides (BDT[a])	2005.67
Irrigation (BDT)	1727.41
Land (hectare)	0.27
% of farmers implying organic manure	0.86
% of farmers cultivating modern variety	0.13
Variables used in the technical inefficiency model	
Mean of share of own land to total land	0.825
Herfindahl index of crop diversification	0.34
Extension service	0.38
Mean of farmers taken agricultural credit	0.274
Annual off-farm income of the household (BDT)	23034
% of farmers using recommended fertilizer dose	0.332
% of farmers living in Pabnadistrict	0.357
% of farmers living in Rajshahi district	0.329

[a] BDT is local Bangladeshi currency known as Bangladeshi Taka One Euro is approximately 97.5 BDT

Hypotheses testing and variance parameters

Several hypothesis tests were conducted to decide whether the frontier model is an appropriate choice rather than a standard mean response or average production function. Also tests were conducted to check the presence of inefficiency and returns to scale in onion production. The first among these was the functional form test, i.e. the test to choose between Cobb–Douglas vs. translog functional form ($H_0 : \beta_{jk}$ for all j and k). Rejection of the null hypothesis through the generalized likelihood ratio (LR) test confirmed that the choice of translog production function is a better representation of the onion production structure, which is in line with many of the earlier literature about Bangladesh agriculture (Wadud and White, 2000; Rahman, 2003; Rahman and Rahman, 2009; Asadullah and Rahman, 2009; Anik and Bauer, 2015) (Table 2).

Table 2
Test of hypotheses

Null hypothesis for functional form test: Cobb Douglas versus translog model ($H_0 : \beta_{jk} = 0$), all coefficients of the interaction variables are zero)	
Likelihood test statistics χ^2	111.33
p value (Prob > χ^2)	0.000
Decision	Reject
Null hypothesis for frontier test (M3T): No inefficiency component in the model	
z statistic	-5.472
p value (Prob <= z)	0.000
Decision	Reject
Null hypothesis for no inefficiency effects ($H_0 : \delta_0 = \delta_1 = ... = \delta_8$)	
Likelihood test statistics (χ^2)	58.11
p value (Prob > χ^2)	0.000
Decision	Reject
Returns to scale (Scale economy of $\varepsilon_y < 1$) ($H_0 : \sum\beta_m = 1$ for all m)	
χ^2 value	0.34
Degrees of freedom	1
p value (Prob > χ^2)	0.5603
Decision	Not rejected

The M3T test checks the sign of the third moment and the skewness of the OLS residuals of the data to justify the use of the stochastic frontier framework (and hence the maximum likelihood estimation procedure) (Rahman et al., 2009). The negative test statistics implies that the OLS residuals are negatively skewed and technical inefficiency is present; as in the stochastic frontier framework, the third moment is also the third sample moment of the u_i (Omer et al., 2007; Rahman and Hasan, 2008). Rejection of the null hypothesis of 'no inefficiency component' establishes that use of the stochastic frontier framework is justified. Almost unitary and significantly different from zero coefficient of γ presented in lower part of Appendix 1 also indicates presence of inefficiency in the production process. Rejection of the null hypothesis of no inefficiency effects (i.e. $H_0 : \delta_0 = \delta_1 = ... = \delta_8$) implies that there are significant technical inefficiency effects in onion production (Table 2).

Sauer et al. (2006) suggested for two different regularity conditions check in translog production frontier. These are: (i) monotonicity, i.e. positive marginal products, with respect to all inputs ($\partial_y/\partial x_i > 0$) and thus non-negative production elasticities; and (ii) diminishing marginal productivity ($\partial^2_y/\partial x^2 < 0$) with respect to all inputs (i.e. the marginal

Appendix 1

Maximum likelihood estimates of stochastic translog production frontier for the sample farmers

Variables	Coefficient	SE
Production function		
Ln Labour	0.241**	0.128
Ln Seed	0.188***	0.065
Ln Fertilizer	0.091	0.174
Ln Pesticide	0.039	0.080
Ln Irrigation	0.015	0.133
Ln Land	0.326***	0.059
0.5 * (Ln Labour)^2	-0.082	0.171
0.5 * (Ln Seed)^2	0.081	0.060
0.5 * (Ln Fertilizer)^2	-0.080	0.143
0.5 * (Ln Pesticide)^2	0.003	0.007
0.5 * (Ln Irrigation)^2	0.072	0.132
0.5 * (Ln Land)^2	-0.607	0.630
Ln Labour X Ln Seed	0.259***	0.057
Ln Labour X Ln Fertilizer	0.090	0.104
Ln Labour X Ln Pesticides	0.004	0.019
Ln Labour X Ln Irrigation	-0.175**	0.094
Ln Labour X Ln Land	-0.308	0.359
Ln Seed X Ln Fertilizer	0.081	0.057
Ln Seed X Ln Pesticides	-0.001	0.013
Ln Seed X Ln Irrigation	-0.009	0.044
Ln Seed X Ln Land	-0.491***	0.155
Ln Fertilizer X Ln Pesticides	-0.017	0.030
Ln Fertilizer X Ln Irrigation	-0.125	0.113
Ln Fertilizer X Ln Land	0.818**	0.439
Ln Pesticides X Ln Irrigation	0.039	0.043
Ln Pesticides X Ln Land	-0.357	0.368
Ln Irrigation X Ln Land	0.469	0.376
Varietal dummy	0.150**	0.064
Compost dummy	-0.032	0.058
Constant	8.260***	0.145
Technical inefficiency predictors		
Extension service	-0.887**	0.458
Credit	0.142	0.151
Own land share	-0.305**	0.169
Off-farm income	-0.000004*	0.000
Herfindahl index of crop diversification	1.990***	0.837
Recommended fertilizer dose	-0.244**	0.143
Dummy for Rajshahi district	3.211***	0.503
Dummy for Pabna district	1.828***	0.506
Constant	-1.813***	0.699
Variance parameters		
$\sigma^2 = \sigma^2_u + \sigma^2_v$	0.349***	0.040
$\gamma = \sigma^2_u/(\sigma^2_u + \sigma^2_v)$	0.925***	0.021
log likelihood function	-87.561	

Note: *, **, and *** indicate significant at 10%, 5% and 1% levels, respectively.

products, apart from being positive should be decreasing in inputs). Results in Table 3 demonstrate that both these conditions are fulfilled for all the inputs.

Table 3
Regularity conditions check

Variables	Monotonicity ($\partial_y/\partial x_i > 0$) for every input		Diminishing marginal productivity ($\partial^2_y/\partial x^2 < 0$) for every input	
	Value	Outcome	Value	Outcome
Labour	32.99	Fulfilled	-1.12	Fulfilled
Seed	284.83	Fulfilled	-20.31	Fulfilled
Fertilizer	2.29	Fulfilled	-105.65	Fulfilled
Pesticides	0.12	Fulfilled	-42497.73	Fulfilled
Irrigation	0.04	Fulfilled	-56985.05	Fulfilled
Land	5911.45	Fulfilled	-0.61	Fulfilled

Drivers of onion production

The parameter estimates of the translog stochastic production frontier function using MLE procedure are presented in Appendix 1. Among the production inputs land, labour and seed have significant effects on production. The most dominant driver is land with elasticity value estimated at 0.33, implying that a 1% increase in land area will increase onion production by 0.33%. Past studies observed that, in the Asian context, output elasticity of land is notably higher than the output elasticity of other inputs such as labour and capital (Lau and Yotopulos, 1971). Cornia (1985) found land elasticity is relatively high in land scarce countries (e.g. Bangladesh) and low in land rich countries (e.g. Syria). Studies about Bangladesh rice farming found land to have higher elasticity than other production inputs (Wadud and White, 2000; Rahman, 2003; Asadullah and Rahman, 2009). A 1% increase in labour and seed will result in 0.24% and 0.19% increase in onion production respectively. The positive significant coefficient on the varietal dummy variable means that the cultivation of modern variety significantly contributes to production, which econometrically confirms the conclusion drawn by Anik and Salam (2015) (Table 4).

Although the sum of mean output elasticities for all the inputs is less than one (0.90), the null-hypothesis of constant returns to scale in production cannot be rejected (Table 2). The implication is that farmers are already operating at an optimal scale and a proportional increase in inputs will result in the same proportional increase in output. Mari and Lohano (2007) also reported constant returns to scale for onion farmers in Sindh province of Pakistan.

Table 4
Elasticities of the input and efficiency variables

Variables	Value
Input elasticities	
Labour	0.241**
Seed	0.188***
Fertilizer	0.091
Pesticide	0.039
Irrigation	0.015
Land	0.326***
Returns to scale for the input variables	0.90
Varietal dummy	0.150**
Compost dummy	-0.032
Efficiency elasticities	
Extension service	0.153**
Credit	-0.011
Own land share	0.070**
Off-farm income	0.021*
Herfindahl index of crop diversification	-0.187***
Recommended fertilizer dose	0.022**
Dummy for Rajshahi district	-0.124***
Dummy for Pabna district	-0.410***

Note: *, **, and *** indicate significant at 10%, 5% and 1% levels, respectively

Technical efficiency in onion production

The summary statistics of technical efficiency scores for the onion growers are presented in Table 5. Figure 1 presents technical efficiency score for each of the farmers along with lower and upper bound of confidence interval of efficiency scores. The estimated mean technical efficiency of 67% implies that a substantial 49% [(100 - 67) ⁄67] of the onion production is lost due to technical inefficiency alone. Baree et al. (2011) estimated technical efficiency of the small, medium and large onion growers in Bangladesh to be 77%, 87% and 84% respectively. In Pakistan, techni-

Table 5
Technical efficiency in rice production

Efficiency levels	Proportion of farmers
Up to 50%	27.50
51-70%	11.43
71-90%	41.43
91% and above	19.64
Efficiency scores	
Mean	0.67
SD	0.26
Min	0.05
Max	0.99

cal efficiency of the onion growers was estimated at 59% (Mari and Lohano, 2007). Farmers exhibit wide range of variation in technical efficiency ranging from 5% to 99%. Wide variation in technical efficiency was also observed in previous studies on rice production in Bangladesh (Wadud and White, 2000; Rahman, 2003; Rahman and Rahman, 2008). The distribution of 95% confidence band of individual farmers shows that farmers operating at a higher level of score can have a higher level of fluctuation in performance as compared to those who are operating at a very low level of efficiency. The implication is that these high performing farmers can lose out more and are quite vulnerable to shocks if something goes wrong in the production process, thereby requiring them to be vigilant throughout the production cycle.

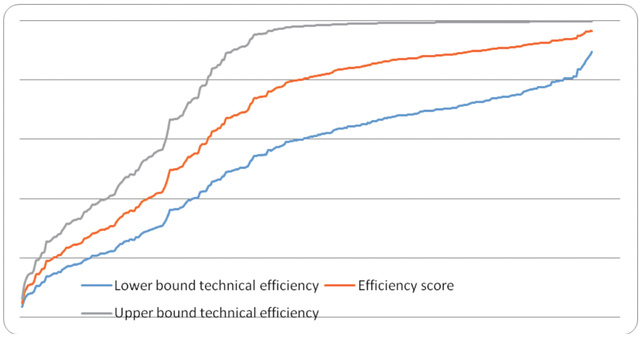

Fig. 1. Efficiency score, lower and upper bound of technical efficiency

Elasticities of variables in the technical efficiency model

The elasticities of the inefficiency variables are presented in the lower part of Table 4. All the inefficiency variables except credit have significant effect on inefficiency. The extension service, own land share, off-farm income, crop diversification and recommended fertilizer dose significantly improve technical efficiency. A 1% increase in the level of crop diversification will increase technical efficiency by 0.19%. The negative elasticity for the Herfindahl index means that the diversified farms are efficient than the specialized farms. The relationship here is in line with Rahman (2009) and Coelli and Fleming (2004). This is because farmers practicing diversification divert their resources and efforts among different competing crops and economise on their use. Extension service plays an important role in increasing farm efficiency. Extension service enables farmers to learn and practice farming operations better and also facilitate in adopting modern technology. The positive contribution of extension service in farm efficiency is well documented in the literature e.g., Sharif and Dar (1996); Wang et al. (1996).

A 1% increase in the household's own land share will significantly enhance technical efficiency by 0.07. Literature argues for higher level of efficiency for the owner operators than the tenants (Coelli et al., 2003; Rahman, 2003). Perhaps the poor quality of land which is generally rented to tenants may explain the differences in efficiency between the tenants and owner operators (Rahman, 2003). A 1% increase in the value of off-farm income will significantly improve technical efficiency by 0.02%, implying that farmers earning relatively more from off-farm sources are efficient. The finding here contradicts with Wang et al. (1996), Rahman (2003) and Asadullah and Rahman (2009). They found situations where households with higher opportunities to engage in non-agricultural activities pay less attention to rice farming and become less efficient. But as onion is a cash crop, it perhaps earns sufficient amount in order to compete with the off-farm income sources. Furthermore, inadequate rural infrastructure may not offer suitable alternative off-farm employment opportunities. In African context it was observed that due to poorly functioning capital market, farmers divert income from non-farm sources to agricultural activities which ultimately improve agricultural productivity (Haggblade et al., 1989; Hazell and Hojjati, 1995).

Farmers applying recommended fertilizer dose perform significantly better by 0.02% higher level of technical efficiency, as expected. Using recommended dose enables farmers to operate near their optimal input bundle; whereas their counterparts deviate away from it. Consequently farmers who use recommended dose become relatively more efficient. Farmers located in Rajshahi and Pabna districts have 0.12% and 0.41% lower level of efficiency as compared with farmers located in Faridpur (Table 4).

Conclusions and Policy Implications

The study attempts to identify the drivers of production and technical efficiency in onion cultivation at the farm level in Bangladesh using a stochastic production frontier approach. Results reveal that land, labour, seed and modern variety are the main drivers of onion production. Constant returns to scale exists in onion production. Substantial level of inefficiency exists in onion production which can be eliminated to boost production. The efficiency drivers are crop diversification, extension services, cultivating in own land, earning from off-farm activities and using recommended doses of fertilizers.

Based on these findings, the following policy interventions are recommended. Investment in extension services is of paramount importance. The Department of Agricultural

Extension (DAE) has the key role in popularizing modern onion varieties. The extension agents have to orient the farmers to improved cultivation practices including selection of improved onion varieties and application of recommended doses for different inputs. As farm level efficiency varies across location, extension programmes should be designed by prioritizing areas with lower efficiency (e.g., Rajshahi and Pabna). Since a number of non-governmental organisation (NGOs) operating in Bangladesh promotes crop diversification and kitchen gardening, they can also potentially contribute to disseminate information on modern technology adoption and improve productivity and efficiency. Another important intervention is land reform programme primarily aimed at improving land ownership of individual farms which will require strong political commitment to address the issue of absentee landlordism, effective redistribution of the 'khas land' (state owned land) amongst landless farmers, enforcement of the ceiling land ownership of 8.5 ha per household which was established since 1984 (CARE, 2003) and facilitation of the smooth operation of the agricultural land market.

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References

Anik, A. R. and S. Bauer, 2015. Impact of resource ownership and input market access on Bangladeshi paddy grower's efficiency. *International Journal of Agricultural Management*, **4** (3): 123-131.

Anik, A. R. and M. A. Salam, 2015. Determinants of adoption of improved onion variety in Bangladesh. *Journal of Agriculture and Environment for International Development*, **109** (1): 71-88.

Appleton, S. and A. Balihuta, 1996. Education and agricultural productivity: evidence from Uganda. *Journal of International Development*, 8: 415-444.

Asadullah, M. N. and S. Rahman, 2009. Farm productivity and efficiency in rural Bangladesh: the role of education revisited. *Applied Economics*, **41** (1): 17-33.

Awal, M. A., S. R. Saha, M. S. Alam and M. A. Matin, 2004. Onion cultivation at farm level: input use. Productivity and Resource Use Efficiency. *Bangladesh Journal of Agricultural Research*, **29** (1): 143-151.

Baree, M. A., M. A. Rahman, M. H. A Rashid, M. N. Alam and S. Rahman, 2011. A comparative study of technical efficiency of onion producing farms in Bangladesh. *Progress in Agriculture*, **22** (1-2): 213-221.

Barghouti, S., S. Kane, K. Sorby and M. Ali, 2004. Agricultural diversification for poor: guidelines for practitioners. Agricultural and Rural Development Discussion Paper # 1, Agriculture and Rural Development Department, *World Bank*.

Battese, G. E. and T. J. Coelli, 1995. A model for technical inefficiency effects in a stochastic frontier production function for panel data. *Empirical Economics*, **20** (2): 325-332.

BBS, 2013. Statistical Yearbook of Bangladesh 2012, *Bangladesh Bureau of Statistics*, *Statistics Division, Ministry of Planning*, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh.

CARE, 2003. Land policy and administration in Bangladesh: A literature review. *CARE Rural Livelihoods Programme*, Dhaka, Bangladesh.

Coelli, T. J. and E. Fleming, 2004. Diversification economies and specialization efficiencies in a mixed food and coffee smallholder farming system in Papua New Guinea. *Agricultural Economics*, 31: 229-239.

Coelli, T. J., S. Rahman and C. Thirtle, 2003. A stochastic frontier approach to total factor productivity measurement in Bangladesh crop agriculture, 1961-92. *Journal of International Development*, **15** (3): 321-333.

Cornia, G. A., 1985. Farm size, land yields and the agricultural production function: An analysis for fifteen developing countries. *World Development*, **13** (4): 513-534.

DAM, 2013. Department of Agricultural Marketing Website. http://www.dam.gov.bd. Accessed 05 November 2013

FAOSTAT, 2015. Food and agriculture organization of the United Nations, FAOSTAT database. http://faostat3.fao.org/download/Q/QC/E (Accessed on 23 August 2015)

Haggblade, S., P. Hazell and J. Brown, 1989. Farm-nonfarm linkages in rural Sub-Saharan Africa. *World Development*, **17** (8): 1173-1201.

Haque, M. A., M. A. M. Miah, S. Hossain, M. S. Rahman and Moniruzzaman, 2011. Profitability of onion cultivation in some selected Areas of Bangladesh. *Bangladesh Journal of Agricultural Research*, **36** (3): 427-435.

Hazell, P. B. and B. Hojjati, 1995. Farm/non-farm growth linkages in Zambia. *Journal of African Economies*, **4** (3): 406-435.

Husain, A. M. M., M. Hossain and A. Janaiah, 2001. Hybrid rice adoption in Bangladesh: Socioeconomic assessment of farmers' experiences. BRAC Research Monograph Series No 18, *BRAC*, Bangladesh, Dhaka.

Kasem, S. and G. B. Thapa, 2011. Crop diversification in Thailand: Status, determinants, and effects on income and use of inputs. *Land Use Policy*, **28** (3): 618-628.

Lau, L. and P. Yotopulos, 1971. A test for relative efficiency and application to Indian agriculture. *The American Economic Review*, **61** (1): 94-109.

Mari, F. and H. D. Lohano, 2007. Measuring production function and technical efficiency of onion, tomato, and chillies farms in Sindh, Pakistan. *The Pakistan Development Review*, **46** (4): 1053-1064.

Omer, A., U. Pascual and N. P. Russell, 2007. Biodiversity conservation and productivity in intensive agricultural systems. *Journal of Agricultural Economics*, 58: 308-329.

Planning Commission, 2009. Steps towards change – national strategy for accelerated poverty reduction II (revised). FY 2009-11. *Government of the People's Republic of Bangladesh*, Dhaka.

Rahman, S., 2003. Profit efficiency among Bangladeshi rice farmers. *Food Policy*, **28** (5-6): 487-504.

Rahman, S., 2008. Determinants of crop choice among Bangladeshi farmers: A bivariate probit analysis. *Asian Journal of Agriculture and Development*, **5** (1): 29-41.

Rahman, S., 2009. Whether crop diversification is a desired strategy for agricultural growth in Bangladesh. *Food Policy*, **34** (4): 340-349

Rahman, S. and M. K. Hasan, 2008. Impact of environmental production conditions on productivity and efficiency: a case study of wheat farmers in Bangladesh. *Journal of Environmental Management*, **88**: 1495-1504.

Rahman, S. and M. Rahman, 2008. Impact of land fragmentation and resource ownership on productivity and efficiency: The case of rice producers in Bangladesh. *Land Use Policy*, **26** (1): 95-103.

Rahman, S., A. Wiboonpongse, S. Sriboonchitta and Y. Chaovanapoonphol, 2009. Production efficiency of Jasmine rice producers in Northern and North-eastern Thailand. *Journal of Agricultural Economics*, **60** (2): 419-435.

Sauer, J., K. Frohberg and H. Hockmann, 2006. Stochastic efficiency measurement: The curse of theoretical consistency. *Journal of Applied Economics*, **9** (1): 139-165.

Sharif, N. R. and A. Dar, 1996. An empirical study of the patterns and sources of technical inefficiency in traditional and HYV rice cultivation in Bangladesh. *Journal of Development Studies*, 32: 612-629.

Tzouvelekas, V., C. J. Pantzios and C. Fotopoulos, 2001. Technical efficiency of alternative farming systems: The case of Greek organic and conventional olive growing farms. *Food Policy*, **26** (6): 549-569.

Wadud, A. and B. White, 2000. Farm household efficiency in Bangladesh: A comparison of stochastic frontier and DEA methods. *Applied Economics*, **32 (13)**: 1665-1673.

Wang, J., G. L. Cramer and E. J. Wailes, 1996. Production efficiency of Chinese agriculture: evidence from Rural Household Survey data. *Agricultural Economics*, 15: 17-28.

Weir, S. and J. Knight, 2004. Externality effects of education: dynamics of the adoption and diffusion of an innovation in rural Ethiopia. *Economic Development and Cultural Change,* **53**: 93-113.

Wilson, P., D. Hadley, S. Ramsden and L. Kaltsas, 1998. Measuring and explaining technical efficiency in UK potato production. *Journal of Agricultural Economics,* **48** (3): 294-305.

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